

Childhood Obesity: Trends and Potential Causes

Patricia M. Anderson and Kristin F. Butcher

Summary

The increase in childhood obesity over the past several decades, together with the associated health problems and costs, is raising grave concern among health care professionals, policy experts, children's advocates, and parents. Patricia Anderson and Kristin Butcher document trends in children's obesity and examine the possible underlying causes of the obesity epidemic.

They begin by reviewing research on energy intake, energy expenditure, and "energy balance," noting that children who eat more "empty calories" and expend fewer calories through physical activity are more likely to be obese than other children. Next they ask what has changed in children's environment over the past three decades to upset this energy balance equation. In particular, they examine changes in the food market, in the built environment, in schools and child care settings, and in the role of parents—paying attention to the timing of these changes.

Among the changes that affect children's energy intake are the increasing availability of energy-dense, high-calorie foods and drinks through schools. Changes in the family, particularly an increase in dual-career or single-parent working families, may also have increased demand for food away from home or pre-prepared foods. A host of factors have also contributed to reductions in energy expenditure. In particular, children today seem less likely to walk to school and to be traveling more in cars than they were during the early 1970s, perhaps because of changes in the built environment. Finally, children spend more time viewing television and using computers.

Anderson and Butcher find no one factor that has led to increases in children's obesity. Rather, many complementary changes have simultaneously increased children's energy intake and decreased their energy expenditure. The challenge in formulating policies to address children's obesity is to learn how best to change the environment that affects children's energy balance.

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The increase in childhood obesity has gained the full attention of health care professionals, health policy experts, children's advocates, and parents. All are concerned that today's overweight and obese children will turn into tomorrow's overweight and obese adults, destined to suffer from all the health problems and health care costs associated with obesity. In this essay, we document trends in children's obesity and examine the underlying causes of the obesity epidemic.

We begin by discussing definitions of overweight and obesity, noting some potential problems. We document trends in adult and childhood obesity, both worldwide and in the United States, over the past three decades, paying particular attention to the timing of the increase in obesity. We preface our analysis of obesity's causes with a brief review of research on children's energy intake and energy expenditure and on what affects children's "energy balance." Research findings support the idea that children who eat more "empty calories" and expend fewer calories through physical activity are more likely to be obese than other children. Finally we examine how the environment in which children are raised might have changed over the past three decades and how these changes might have upset the energy balance equation. Have changes in the food market, in the built environment, in schools and child care settings, and in the role of parents contributed to increased obesity? In particular, we examine whether the timing of the changes in children's environments coincides with the timing of the increase in obesity, making it likely that those changes are driving the increase in children's obesity rates.

Defining Obesity

Typically, obesity and overweight in adults are defined in terms of body mass index (BMI), which in turn is defined as weight in kilograms divided by height in meters squared (kg/m^2).¹ Guidelines issued by the National Institutes of Health consider an adult underweight if his or her BMI is less than 18.5, overweight if BMI is 25 or more, and obese if BMI is 30 or more.²

Use of BMI to assess overweight and obesity in children is more controversial. Because children are growing, the link between adiposity, or "true fatness," and the ratio of their weight to their height may be looser than that of adults. However, William Dietz and Mary Bellizzi, reporting on a conference convened by the International Obesity Task Force, note that BMI offers "a reasonable measure with which to assess fatness in children and adolescents."³ They also conclude that a BMI above the 85th percentile for a child's age and sex group is likely to accord with the adult definition of overweight, and a BMI above the 95th percentile is consistent with the adult definition of obese.⁴ Children are thus defined as being overweight or obese if they have a BMI above given age- and sex-specific percentile cutoffs. These cutoffs, which were set for a base population surveyed in the early 1970s before obesity began to increase, yield a specific, fixed BMI cutoff used to define overweight and obesity for boys and girls of each age.⁵ Later in the article we will use these cutoffs to define obesity using the National Health and Nutrition Examination Surveys (NHANES), a nationally representative sample of U.S. children who were consistently weighed and measured between 1971 and 2002.⁶ The data will show an increase in measured obesity over time if more children in each of the NHANES surveys have a BMI above this fixed cutoff number.

International Trends in Obesity

Obesity is a problem not just in the United States but worldwide. Comparing international obesity rates and trends using BMI, however, is complicated, as the relationship between “true fatness” and height and weight may differ for people in different environments. Some groups, for example, may simply have denser body composition than others. Definitions are particularly complicated in international comparisons of obesity in children. If age- and sex-specific growth patterns in Botswana differ from those in the United States, then obesity definitions based on the same BMI cutoffs are unlikely to yield useful comparisons. Nonetheless, a growing body of literature examining specific populations has concluded that obesity is increasing worldwide.

Table 1 lists adult obesity rates collected by the World Health Organization for selected countries and time periods.¹ Although different countries have different obesity rates, a common pattern across all countries listed, with the exception of Japan, is that adult obesity rates are rising. U.S. adult obesity rates are among the world’s highest (compare the rates in table 1 with those in figure 1 on page 23). In 1995, for example, 15 percent of men and 16.5 percent of women in England were obese. In the United States (in the nearest time period for which data are available), the share was more than 20 percent for men and women combined. Only the former German Democratic Republic has obesity rates that are similar to those in the United States for similar years. The rates are still quite low in Japan, Finland, Sweden, and the Netherlands.

Many studies of individual countries have also noted increases in childhood obesity in recent years. Helen Kalies and two colleagues found that obesity rates rose from 1.8 to 2.8 percent among preschool children in Germany between 1982 and 1997.² Among children aged seven to eleven in England, the prevalence of overweight and obesity increased from less than 10 percent for both boys and girls in the mid-1970s to more than 20 percent for girls and more than 15 percent for boys by 1998.³ In urban areas in China, the prevalence of obesity increased among children aged two to six from 1.5 percent in 1989 to 12.6 percent in 1997. In rural China over the same period, obesity rates fell.⁴ Though childhood obesity is on the rise worldwide, the patterns differ, in expected ways, between developing and developed countries. In the former, obesity may coexist with undernutrition, with children in the relatively affluent urban areas more likely to be obese than their rural counterparts.

1. World Health Organization, “Obesity: Preventing and Managing the Global Epidemic” (Geneva: WHO, 1998).

2. Helen Kalies, J. Lenz, and Rüdiger von Kries, “Prevalence of Overweight and Obesity and Trends in Body Mass Index in German Pre-School Children, 1982–1997,” *International Journal of Obesity* 26 (2002): 1211–17.

3. Tim J. Lobstein and others, “Increasing Levels of Excess Weight among Children in England,” *International Journal of Obesity* 27 (2003): 1136–38.

4. Juhua Luo and Frank B. Hu, “Time Trends of Obesity in Pre-School Children in China from 1989 to 1997,” *International Journal of Obesity* 26 (2002): 553–58.

Obesity in the United States

In the United States obesity rates have increased for all age groups over the past thirty years. Figure 1 shows the share of the U.S. population, by age group, that is obese based on the BMI cutoffs described above.⁷ During

1971–74 about 5 percent of children aged two to nineteen years were obese. By 1976–80 the share obese was slightly higher, but between 1980 and 1988–94 the share obese nearly doubled. By 1999–2002 nearly 15 percent of U.S. children were considered obese. Al-

Table 1. Obesity Rates, by Country and Year

| Country | Year | Prevalence of obesity (percent) | |
|--|---------|---------------------------------|-------|
| | | Men | Women |
| Australia (aged 25–64) | 1980 | 9.3 | 8.0 |
| | 1989 | 11.5 | 13.2 |
| Brazil (aged 25–64) | 1975 | 3.1 | 8.2 |
| | 1989 | 5.9 | 13.3 |
| Canada (aged 20–70 in 1978 and 18–74 in 1986–90) | 1978 | 6.8 | 9.6 |
| | 1986–90 | 15 | 15 |
| England (aged 16–64) | 1980 | 6.0 | 8.0 |
| | 1995 | 15.0 | 16.5 |
| Finland (aged 20–75) | 1978–79 | 10 | 10 |
| | 1991–93 | 14 | 11 |
| Former German Democratic Republic (aged 25–65) | 1985 | 13.7 | 22.2 |
| | 1992 | 20.5 | 26.8 |
| Japan (aged 20 and older) | 1976 | 0.7 | 2.8 |
| | 1993 | 1.8 | 2.6 |
| Netherlands (aged 20–29) | 1987 | 6.0 | 8.5 |
| | 1995 | 8.4 | 8.3 |
| Sweden (aged 16–64) | 1980–81 | 4.9 | 8.7 |
| | 1988–89 | 5.3 | 9.1 |

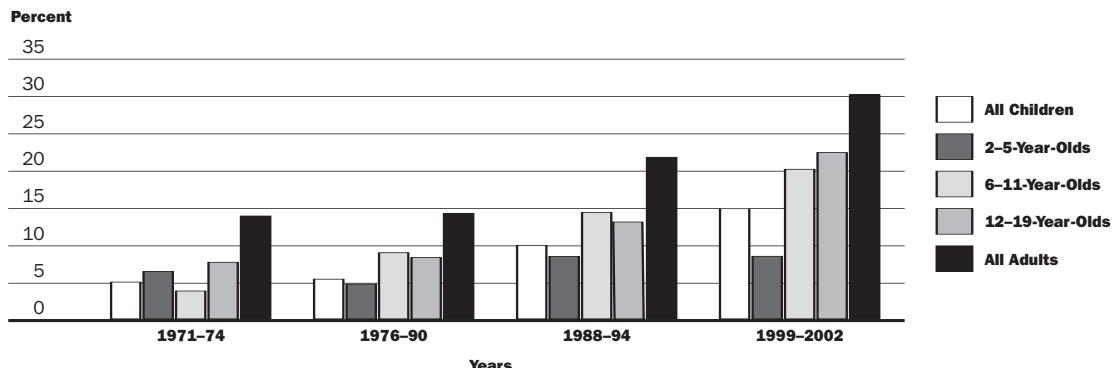
Source: World Health Organization, "Obesity: Preventing and Managing the Global Epidemic" (Geneva: WHO, 1998). European countries: table 3.4, page 25; Western Pacific countries: table 3.7, page 28; the Americas: table 3.2, page 22. An individual is categorized as obese if he or she has a body mass index of 30 or above.

though the rates of obesity were higher for older children in every survey, all age groups showed an increase in obesity. Rates for boys and girls were nearly identical. Adult obesity also steadily increased, with the share of adults defined as obese larger than that of children in any given time period. Obesity rates increased for both men and women, though women had higher rates than men.⁸

Logically enough, increasing childhood obesity is related to increasing adult obesity. Obese children are much more likely than normal weight children to become obese adults. Obesity even in very young children is correlated with higher rates of obesity in adulthood. A study from the late 1990s shows that 52 percent of children who are obese between the ages of three and six are obese at age twenty-five as against only 12 percent of normal and underweight three- to six-year-old children.⁹

Although the obese share of the population is expected to increase with age, obesity today is increasing with age more quickly than it did thirty years ago. Researchers in 1971 trying to project what share of ten-year-olds that year would be obese by the time they turned forty in 2001 would have predicted the share to be between 10 and 15 percent. But in 1999–2002 the share was close to 30 percent. This change in the relationship between age and obesity has important implications for predicting what share of the population will have obesity-related health problems as the population ages.

The precise timing of the increase in obesity in the United States is also important for researchers attempting to identify its causes. As shown in figure 1, the obese share of the U.S. population for both children and adults was fairly stable between 1971–74 and 1976–80 and only began to increase thereafter. Thus, in

Figure 1. Percentage of U.S. Population That Is Obese

Source: Authors' calculations from National Health and Nutrition Examination Surveys (NHANES).

the search for causes of the obesity epidemic, researchers focus particularly on any environmental changes that began between 1980 and 1988 and continued during the 1990s.

Before beginning our analysis of these causes, we want to document a few more important features of the trend in obesity. As figure 2 shows, obesity rates are higher among minority and low-income children than among children as a whole.¹⁰ Although obesity increased for all children, it increased more for children in low-income families and increased the most for African American children.

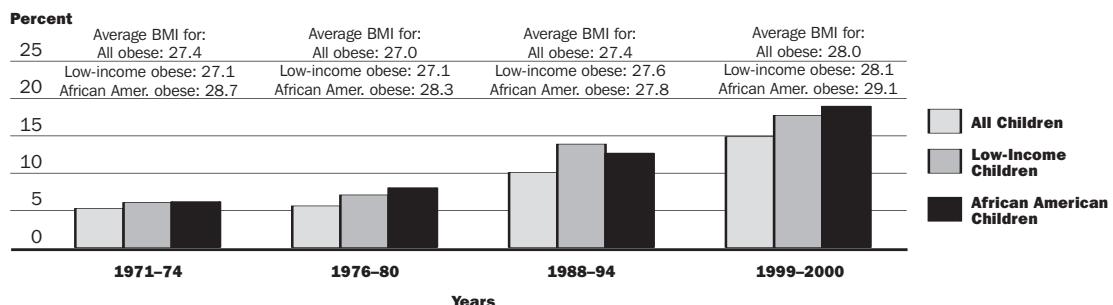
In addition to examining changes in obesity rates it is important to examine how the distribution of BMI has also changed. Obesity rates alone may be misleading because small changes in BMI may result in large changes in obesity rates. Suppose, for example, that in one year a large group of children with BMIs just below the obesity cutoff gained a few pounds, thus tipping over into the obese category. Obesity rates would increase, even though the underlying health of the population did not change much. Distribution of BMI is also important in comparing obesity rates between groups. For example, if obesity rates were higher among low-income children simply because a slightly higher fraction of children had

BMIs above the obesity cutoff, differences in obesity rates would not be expected to translate into differences in health outcomes.

An examination of the data indicates that movements of people from just below to just above the BMI cutoffs cannot explain changes in obesity in the 1990s. By 1999–2002 not only was a larger share of children obese, those who were obese were also heavier than in the past. Figure 2 charts changes in the percentage of children who are obese for all children, for low-income children, and for African American children; it also reports average BMI among the obese for these groups. Average BMI among all obese children increased little between 1971–74 and 1988–94, implying that the increase in obesity rates was mostly due to a higher fraction of children "tipping" over the obesity cutoff. But by 1999–2002 average BMI had increased among obese children. The increase in average BMI among obese children between 1971–74 and 1999–2002 corresponds to an increase in body weight for a 4'6" tall child from about 113.6 pounds to 116.1 pounds.

Figures 3 and 4 cast more light on the changing BMI distribution. They show the share of adults and children, respectively, that is overweight (but not obese) and the share obese.

Figure 2. Percentage of Children Who Are Obese and Average BMI among Obese Children, by Group



Source: Authors' calculations from National Health and Nutrition Examination Surveys (NHANES).

They also show BMI at the median of the distribution (half of the people are heavier) and at the 95th percentile of the distribution (5 percent of the people are heavier). After 1976-80 the share overweight and the share obese increase for both adults and children, but the share obese increases more rapidly. Similarly, although the median BMI increases after 1980, BMI at the 95th percentile increases more quickly.

Two examples illustrate the consequences of these changes in the distribution of BMI. An adult woman who is 5'4" tall, with a BMI at the median, would weigh 143.3 pounds in 1971-74. By 1999-2002 she would weigh 157.3 pounds, a gain of 14 pounds, or 9.8 percent. But a 5'4" tall woman with a BMI at the 95th percentile would go from 197.5 to 231.9 pounds over the same period—a gain of 34.4 pounds, or 17.4 percent. For children, the difference in the median and upper-tail weight gain is even more striking. A 4'6" child with the median BMI would gain 4.6 pounds over this period for a 6.3 percent increase (73.4 to 78.0 pounds). But a child at the 95th percentile would gain about 19 pounds for a 17.5 percent weight gain (108.3 to 127.3 pounds).

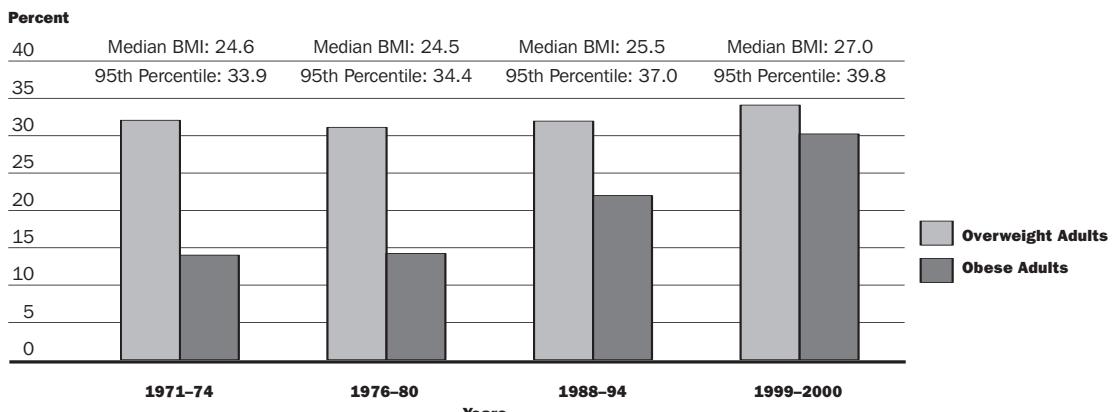
In short, BMI is becoming more unequally distributed: the heavy have gotten much

heavier. Furthermore, obesity is not evenly distributed across socio-demographic groups. Indeed, given the pattern of changes in the BMI distribution, obesity appears to have much in common with other diseases: everyone may be exposed to a given change in the environment, but only those with a susceptibility to the given disease will come down with it. For those with a susceptibility to obesity, the conditions appear to be right for their disease to flourish.

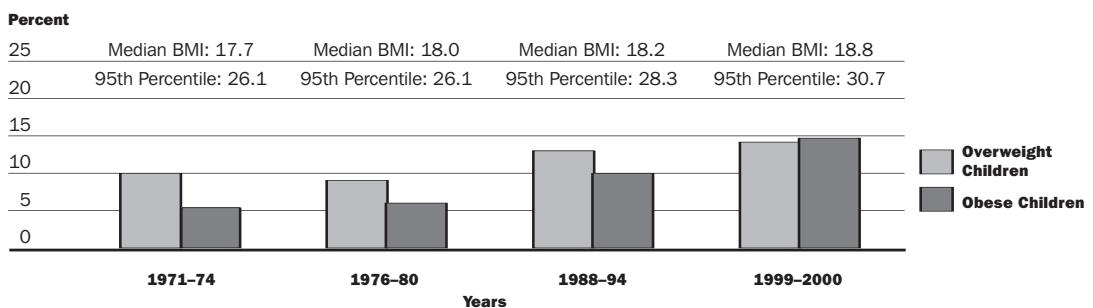
A Question of Energy Balance

Clearly, overweight and obesity are increasing in children and adults. Less clear are the causes of this increase, although the basic physiology of weight change is well understood: weight is gained when energy intake exceeds energy expenditure. Although certain endocrinological or neurological syndromes, including Praeder Willi, Klinefelter's, Frohlich's, Lawrence Mood Biedl, Klein-Levin, and Mauriac syndromes, can lead to overweight—and although these syndromes are often tested for, especially in cases of childhood obesity—less than 5 percent of obesity cases result from these "endogenous" factors.¹¹

Genetics also plays a big role in obesity. Recent studies have concluded that about 25 to 40 percent of BMI is heritable.¹² Identical

Figure 3. Percentage of Adults Who Are Overweight or Obese

Source: Authors' calculations from National Health and Nutrition Examination Surveys (NHANES).

Figure 4. Percentage of Children Who Are Overweight or Obese

Source: Authors' calculations from National Health and Nutrition Examination Surveys (NHANES).

twins raised apart, for example, have been found to have a correlation in BMI of about 0.7 (a correlation of 1 is perfect), only slightly lower than that of twins raised together.¹³ Of course, the gene pool does not change nearly rapidly enough for a change in genes to explain the recent increase in childhood overweight and obesity. But it does appear that certain people may have a higher genetic susceptibility to weight gain. Thus, when identical twins are subjected to an overfeeding regimen, the correlation of the weight gain *within* twin pairs is significantly higher than that *between* twin pairs.¹⁴ But as important as genes are, the primary focus in the search for the causes of rising obesity must be on changes in energy balance.

Maintaining a stable weight requires a delicate balance between energy intake and energy expenditures. Very young children seem capable of adjusting their intake to match their outflow, but as children grow up, they seem to lose this apparently innate ability.¹⁵ Their food intake, rather than being based on energy needs, is influenced by external cues, such as the amount of food presented.¹⁶ Much research on childhood obesity focuses on the role of energy intake, with most studies analyzing a particular source.

Studies of Energy Intake

Fast food is a common subject of such studies. Cross-sectional studies have established that individuals consuming fast-food meals

have higher energy intake with lower nutritional values than those not consuming fast food.¹⁷ Such a finding, however, does not guarantee that children consuming more fast food will be more likely to be overweight. In fact, Cara Ebbeling and several colleagues find that although both overweight and lean adolescents consume more calories when eating fast food, the lean compensate for that energy intake, while the overweight do not.¹⁸ A recent long-term study of eight- to twelve-year-old girls did find that those eating fast food two or more times a week at baseline, when 96 percent of study subjects were lean, had larger weight gains at a three-year follow-up.¹⁹ But the study covers only middle-class, white females. And although its long-term design makes it more reliable than a cross-sectional study, it still does not conclusively prove a causal effect of fast food. Unobserved characteristics of the girls that may be correlated with both fast-food consumption and weight gain may be the true causal culprit.

Another frequently studied source of energy is sweet beverages, mainly soft drinks but also juice. As with fast food, studies generally establish that drinking these beverages results in higher overall energy intake. Several studies have also found a positive link between overweight and soft drink consumption.²⁰ Findings on juice consumption have been more mixed; cross-sectional studies find a link, but some long-term studies do not.²¹ More recently, however, a long-term study of preschoolers has found a positive link between all sweet beverages (including soda, juice, and other fruit drinks) and overweight.²² Another recent study looks at repeated cross-sections of fifth graders in one school and finds a positive, but not significant, relationship between sweetened beverage consumption and BMI.²³ Finally, another study uses a long-term design similar to that of

the fast-food study just noted. Children aged nine to fourteen in 1996 were followed annually through 1998. For both boys and girls, consumption of sugar-added beverages implied small increases in BMI over the years.²⁴

Another much-studied source of energy intake is snacks. Although snack foods tend to be energy dense, implying that snacking may increase overall energy intake, snacking does not appear to contribute to childhood overweight. In a simple cross-sectional study comparing obese and non-obese adolescents, Linda Bandini and several colleagues find that energy intake from snacks is similar for both groups.²⁵ They conclude that obese adolescents eat no more “junk” food than non-obese adolescents, and thus the former’s source of energy imbalance must lie elsewhere. A recent long-term study by Sarah Phillips and colleagues comes to a similar conclusion after collecting information from eight- to twelve-year-old girls annually for ten years.²⁶ The study finds no relationship between consuming snack foods (such as chips, baked goods, and candy) and BMI, although as in the beverage-specific studies just noted, it does find a relationship between BMI and soda.

Studies of Energy Expenditure

The other, equally important side of the energy balance equation is energy expenditures, both through physical activity and through dietary thermogenesis and the basal metabolic rate (BMR). Dietary thermogenesis refers to the energy required to digest meals, and the basal metabolic rate refers to the energy required to maintain the resting body’s functions. For sedentary adults, physical activity is responsible for 30 percent of total energy expenditure, dietary thermogenesis for 10 percent, and BMR for the remaining 60 percent.²⁷ Several studies examine

whether a low BMR is responsible for overweight in children. For example, in a study of both obese and non-obese adolescents, Bandini, Dale Schoeller, and William Dietz find that obese teens do not have lower-than-average BMR, and thus lowered energy expenditure through BMR is not the cause of maintained obesity in adolescents.²⁸

The lack of evidence that BMR affects childhood overweight and obesity argues for a research focus on physical activity—or the lack thereof. So far, though, studies of the link between physical activity and BMI have had mixed results.²⁹ One reason why researchers have difficulty proving that physical activity affects BMI may be that BMI is a potentially poor measure of adiposity in the presence of significant lean muscle mass. A study of twelve-year-old French children bears out this hypothesis. Looking at both BMI and waist circumference, researchers find that physical activity is linked with smaller waist circumference for both boys and girls but with lower BMI only for girls.³⁰ Although findings from cross-sectional studies have been somewhat mixed, long-term studies have associated increases in activity and decreases in BMI.³¹

Researchers have found much stronger links between sedentary activities, especially television viewing, and overweight and obesity. That said, at least one study that investigated the effect of television watching on physical activity found none.³² Interestingly, it found computer use, reading, and homework time associated with higher levels of physical activity. The relationship, however, is just a cross-sectional correlation among these activities. It may be that the parents who encourage reading and homework and buy their children computers also encourage more physical activity.

William Dietz and Steven Gortmaker produced the canonical study on television's role in childhood obesity, finding that each additional hour of television per day increased the prevalence of obesity by 2 percent.³³ They note that television viewing may affect weight in several ways. First, it may squeeze out physical activity. Second, television advertising may increase children's desire for, and ultimately their consumption of, energy-dense snack foods. Third, watching television may

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go hand in hand with snacking, leading to higher energy intake among children watching television. Robert Klesges, Mary Shelton, and Lisa Klesges even concluded that children's metabolic rate was lower while watching television than while at rest.³⁴ That finding, however, has not been replicated, and later studies find no effect.³⁵

Research on the relationship among television viewing and physical activity and overweight has mixed findings. Although many studies observe a positive relationship between television viewing and childhood obesity, Thomas Robinson and several colleagues find only a weak relationship (but William Dietz points out several potential methodological problems with this study), and Elizabeth Vandewatter and colleagues find none at all.³⁶ These mixed findings, though, tend to come from

observational or prospective studies. More rigorous experimental studies consistently find that reducing children's television watching lowers their BMI.³⁷ Because these experimental studies can establish causality while the others do not, it seems reasonable to conclude that watching television does contribute to childhood obesity, despite the overall mixed findings of past studies.

Studies of Other Correlates of Obesity

Overall, then, much research on childhood obesity's possible causes focuses on factors that are expected to affect either the child's energy intake or energy expenditure. Another line of research, however, simply documents childhood characteristics that are correlated with overweight, but it either does not or cannot determine their effects on the energy balance equation. Many studies, for example, document that children from certain demographic groups are more likely than other children to be overweight. As noted, data from the NHANES show that African American and lower-income children have a higher incidence of obesity than children overall. Using data from the National Longitudinal Survey of Youth, Richard Strauss and Harold Pollack demonstrate that both African American and Hispanic children are more likely to be overweight than white non-Hispanic children.³⁸ They also find a negative relationship between income and rates of overweight among whites only; the relationship for Hispanics is insignificant; and for African Americans, slightly positive. The study also documents regional differences, with children in the South and the West most likely to be overweight. It finds no significant difference between rural and urban children, although a recent study in Pennsylvania found nearly 20 percent of seventh graders from rural districts to be overweight compared to just 16 percent from urban districts.³⁹

One other repeatedly analyzed characteristic—having been breast-fed as an infant—does not clearly line up with the energy balance equation. Beginning with Michael S. Kramer's work, many cross-sectional studies have found that older children are more likely to be lean if they were breast-fed.⁴⁰ But other studies have had somewhat more mixed findings.⁴¹ More recently, though, Stephan Arenz and colleagues, in a comprehensive review of past studies, conclude that breast-feeding does seem to have a consistent negative effect on obesity, albeit a small one.⁴² As William Dietz makes clear, the mechanism by which infant breast-feeding may affect weight at later ages is not certain.⁴³ One possibility is an endocrine response to breast milk. Another is that mothers have greater discretion over how much they feed their infants when they bottle-feed. Breast-feeding may even affect future food preferences. It is also possible that the relationship is purely an artifact of the cross-sectional study design. That is, the types of mothers who do and do not breast-feed may put into practice different nutritional and activity standards for their children as they grow up. Some evidence for this possibility can be found in a study by Melissa Nelson, Penny Gordon-Larsen, and Linda Adair, which confirms the cross-sectional finding of a link between breast-fed infants and normal-weight older children using long-term data from the National Longitudinal Study of Adolescent Health.⁴⁴ When using sibling pairs to control for unobserved maternal factors, however, they find no effect of breast-feeding on weight. In other words, a breast-fed child is no more likely to be thin than his or her sibling who was not breast-fed. Although this finding provides compelling evidence that breast-feeding does not affect children's weights, two considerations temper this conclusion. First, the sample of families

in which one sibling is breast-fed and another is not is small, perhaps making it difficult to identify statistically significant effects of breast-feeding on weight. Second, with sibling pairs where only one is breast-fed, the issue is why the mother made different decisions. It may be that the decisions were related to factors that ultimately affected the children's weight.

Taken together, what do these studies on the energy balance have to say about the causes of increasing childhood overweight and obesity? Most studies do not determine clear causality, but rather they reveal only cross-sectional correlations. In the stronger long-term studies, many of the samples are relatively unrepresentative (for example, middle-class girls from a specific region), making it unclear whether the findings are broadly applicable. Even for studies replete with representative, long-term evidence (for example, the role of television), the question is whether the timing of the exposure matches the timing of childhood obesity trends.

Changes in the Determinants of Energy Balance

A range of environmental changes may have affected children's energy balance over the past several decades. Combined with a potential genetic susceptibility, these changes may have contributed to the increase in childhood overweight and obesity. In this section we consider four possible changes in the environment: the food market, the built environment, schools and day care, and parents. Subsequent articles in this volume discuss each in more detail.

Changes in the Food Market

Despite a lack of abundant, clearly causal evidence, researchers find many correlations between some types of energy intake and

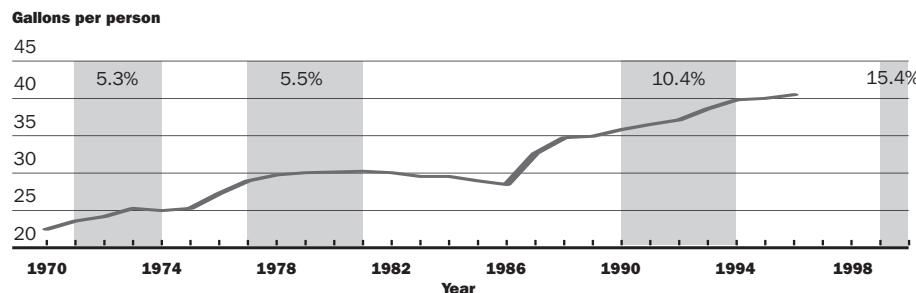
childhood obesity and overweight. As noted, probably the strongest evidence is for the role of soft drinks, followed by slightly mixed findings on the role of fast food. Very little evidence exists that snack foods have a specific effect. But even without a "smoking gun" in terms of energy intake, it is clear that more food, without a concomitant increase in energy expenditure, will result in weight gain. Could changes in the food market in the

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past several decades have caused the increase in childhood overweight and obesity? Judy Putnam and Shirley Gerrior analyze changes in the U.S. food supply and find a marked increase in overall consumption of carbonated soft drinks in the past several decades.⁴⁵ The consumption of regular (non-diet) sodas trended slightly upward in the 1970s, remained fairly stable in the early 1980s, and then exploded starting in 1987, continuing to rise steadily through the 1990s. Figure 5 illustrates this trend, superimposing children's obesity rates over the four periods for which NHANES data are available.

On first glance, the timing of the increase in soda consumption, which tracks closely the trends in increasing childhood obesity, suggests that soda consumption may well be a contributor. But the trend is for overall consumption and includes that of adults as well as

Figure 5. Annual Regular (Non-Diet) Soft Drink Consumption



Sources: NHANES data; regular soft drink consumption data for the United States overall are from Judy Putnam and Shirley Gerrior, "Trends in the U.S. Food Supply, 1970-97," in *America's Eating Habits: Changes and Consequences*, edited by Elizabeth Frazao, USDA Agriculture Information Bulletin no. 750 (Washington: USDA, 1999), pp. 133-59 (www.ers.usda.gov/publications/aib750/ [September 26, 2005]).

Notes: Shaded areas represent years over which BMI measures are available. The percentage of children overweight in those data is shown.

children. Simone French, Bing-Hwan Lin, and Joanne Guthrie, however, document that children's consumption has risen, with the average intake more than doubling from five to twelve ounces a day.⁴⁶ Among those children who drink sodas (a share that increased from 37 to 56 percent), average consumption rose 50 percent, from 14 to 21 ounces. The two data points of this study, one from 1977-78 and one from 1994-98, make it impossible to pinpoint whether the increase occurred mainly in the late 1980s, as it did for overall soft drink consumption. But to the extent that children's consumption mirrored the overall trends, and given the significant effect on obesity that researchers have found for soft drinks, increased consumption may have contributed to the recent trends in obesity. The question then becomes, What led to an increase in soft drink consumption? Certainly, spending for advertising soft drinks has been on the rise—from \$541 million in 1995 to \$799 million in 1999, an almost 50 percent increase.⁴⁷ By contrast, overall food-related advertising over the period increased less than 20 percent, from \$9.8 billion to \$11.6 billion.

Although beverage advertising appears to have been growing disproportionately, the evidence on whether advertising increases overall con-

sumption of a product—or merely affects relative brand consumption—is somewhat mixed. Some evidence shows that advertising affects food preferences, even of children as young as two.⁴⁸ But Todd Zywicki, Debra Holt, and Maureen Ohlhausen argue that food advertising is not a cause of increasing childhood obesity and point out that children's exposure to advertising has increased little over time.⁴⁹ Howard Taras and Miriam Gage, however, note that commercials have grown shorter over time, thus exposing children to more advertisements. And children's programming had 11 percent more commercials per hour in 1993 than in 1987.⁵⁰ Throughout that period, about half of the ads were for foods and beverages, though only about 6 percent of the beverage advertising was for soft drinks. This study, however, like most studies on children and advertising, focuses only on children's programming. Many children are watching adult programming on television and are thus being exposed to the same advertisements as the general population.

Another possible source of the increase in soft drink consumption is the increase in food consumed away from home. French, Lin, and Guthrie note that the share of soft drinks consumed in restaurants (including fast-food

restaurants) rose more than 50 percent while at the same time the share consumed at home fell almost 25 percent.⁵¹ Consumption of soft drinks from every source has increased over this period, but there has been a shift away from consumption at home. This trend in soft drinks mirrors the overall trend in food consumed away from home. Lin and several colleagues document a jump in the share of calories from food consumed away from home from just 18 percent during 1977–78, to 27 percent by 1987–88, and to 34 percent by 1995.⁵² The increase in food away from home is a major change in the food market. In fact, Shin-Yi Chou and colleagues claim that for adults, up to two-thirds of the increase in obesity since 1980 can be explained by the per capita increase in fast-food restaurants over the period.⁵³ Their methodology, however, does not rule out the possibility that the growth trends in both series are just coincidentally correlated.

Also looking at adults, David Cutler and colleagues argue that the mushrooming of fast-food restaurants is just part and parcel of an overall change in technology, with tastier treats becoming available at lower cost and greater convenience.⁵⁴ They point to snacking as the key source of increased energy intake for adults. As noted, though, there is little evidence for a direct effect of snacking on children's obesity. The change in the food market that remains in play, however, is portion size. As noted, all but the youngest children will eat more when offered larger portions.⁵⁵ Looking at convenience foods (both fast foods and other foods packaged for single-serving consumption), Lisa Young and Marion Nestle document increases in portion sizes.⁵⁶ For 181 products they can identify the date when portion sizes were increased. Throughout the 1970s portion sizes of those products increased rarely—fewer than ten

times every five years. That number doubled during the first half of the 1980s to about twenty and doubled again by the first half of the 1990s to more than forty. During the last half of the 1990s portion sizes increased more than sixty times. This timing too fits relatively closely with the timing of increases in childhood obesity. Thus the increase in childhood overweight may be driven not just by

Consumption of soft drinks from every source has increased over this period, but there has been a shift away from consumption at home. This trend in soft drinks mirrors the overall trend in food consumed away from home.

increased consumption of particular foods, such as sodas, but also by the change in the food market toward larger portion sizes.

No discussion of the food market would be complete without considering prices. Darius Lakdawalla and Tomas Philipson, for example, argue that declines in the relative price of food have led people to eat more—and hence to increased obesity.⁵⁷ They calculate that up to 40 percent of the adult increase in BMI since 1980 can be attributed to growing demand for calories resulting from lower prices. Within food groups, the consumer price index for food away from home rose only slightly more slowly than the index for food at home.⁵⁸ Starting with an index of 100 for 1982–84, the food-at-home index rose to

158.1 in 1997, while the food-away-from-home index rose to 157, making it unlikely that price was a primary cause of this shift in eating patterns. In general, it has been argued that energy-dense foods tend to be less costly than such foods as whole grains, fruits, and vegetables.⁵⁹ But based on scanner data, Jane Reed, Elizabeth Frazao, and Rachel Itsckowitz conclude that it is possible to meet the daily

Thus the increase in childhood overweight may be driven not just by increased consumption of particular foods, such as sodas, but also by the change in the food market toward larger portion sizes.

recommendations of three servings of fruits and vegetables for just 64 cents.⁶⁰ They also note that although consumers may perceive fresh produce as more expensive than processed versions (such as canned, frozen, dried, or juiced), converted from a per-pound price to a per-serving price, 63 percent of fruits and 57 percent of vegetables were cheapest when purchased fresh. These prices, however, do not take into account the implicit time costs associated with preparing fresh foods. We will consider this idea below when we discuss the changing role of parents.

Changes in the Built Environment

We noted earlier the strong theoretical relationship between physical activity and overweight. Although the empirical studies establishing this link are comparatively weak,

changes in children's physical activity should nevertheless be investigated. Historically, physical activity was not something one set out to do; it was simply part of life. In fact, Tomas Philipson and Richard Posner argue that the long-run rise in adult obesity can be traced to technological changes that have made work much more sedentary.⁶¹ Rather than being paid to undertake physical activity, modern Americans must pay, either explicitly in gym fees and equipment costs or implicitly in forgone leisure, to be physically active. Although attractive as a theory of historical trends and of differences between developing and developed countries, the argument provides little insight into the increase in childhood overweight and obesity over the past thirty years. Nonetheless, the basic insight that technological changes have made daily living less physically active can be applied to children. To do that, it is necessary to examine changes in the neighborhoods in which children are growing up.

Urban sprawl increases automobile travel.⁶² Thus as sprawl has expanded, vehicle miles per person have increased. Daily vehicle miles traveled per household were fairly constant between 1977 and 1983, at about 33 and 32, respectively, and then jumped up to 41 in 1990.⁶³ Changes in methodology make it impossible to compare the data for these two periods with data for years after 1990, but the 1990 data can be adjusted to allow such comparisons. The adjusted data show about 50 vehicle miles traveled per household for 1990. The increase continued during the early 1990s, before slowing in the latter half of the decade. The 1995 measure is 57 miles; that for 2001, just 58. An increase in household vehicle miles traveled does not necessarily mean that children are spending more time in the car. But total miles traveled by those under age sixteen follows a pattern

fairly similar to that of people of all ages, with the main difference being that the mileage is fairly steady between 1983 and 1990, climbing slowly for all ages. Both groups then show large increases between 1990 and 1995 and are fairly stable in 2001.

Vehicle miles have risen in part because children are no longer able to walk or bike to school or other activities. In 1977, 15.8 percent of trips by children aged five to fifteen were by foot or bicycle. By 1990 the share had fallen to 14.1 percent; by 1995, to 9.9 percent.⁶⁴ A nationally representative survey in 2002 found that 53 percent of parents drove their children to school, with another 38 percent putting their children on a school bus. Just 17 percent of parents said their children walked to school, while 5 percent said their children rode their bikes.⁶⁵ Of parents with children who did not walk or bike to school, the overwhelming majority, 66 percent, said the reason was that school is too far away. Almost equally common responses, at 17, 16, and 15 percent, respectively, were, "too much traffic and no safe walking route," "fear of child being abducted," and "not convenient for child to walk." "Crime in the neighborhood" and "your children do not want to walk" both tallied a 6 percent response. Interestingly, 1 percent said that there was a "school policy against children walking to school."

The 22 percent of children walking or riding bikes to school in 2002 represents a major decline from the share walking or biking when their parents were children, presumably about twenty to thirty years earlier. Just a little more than 70 percent of the parents reported walking or biking to school as children. Again, the increasing trend toward urban sprawl is presumably at least part of the explanation, with school being too far away. In fact, a study of

South Carolina schools found that children today were much less likely to walk to a school that had been built more recently. More than 20 percent of students in schools built during the 1960s walked to school. For schools built in the 1970s the share dropped below 15 percent, while for those built in the 1980s and 1990s it fell below 5 percent.⁶⁶ Distance is not the only obstacle, however. In the South Carolina study, children living within 1.5 miles of the school were eligible for bus transportation if the walking route was deemed hazardous. For schools built in the 1990s, more than 25 percent of students received such transportation while just a little more than 5 percent did for schools built in the 1960s. The share increased consistently by the decade the school was built.

Overall, then, trends in the built environment have resulted in more car trips and in fewer trips by foot or by bicycle. Most notably, less than a quarter of children walk or bike to school today compared to more than two-thirds a generation ago. Today's lower-density development results in schools being further away from children's homes, and recent growth patterns do not provide safe walking routes. In addition to depriving children of an opportunity for physical activity, the change may have other effects on overall physical activity. Ashley Cooper and her colleagues find that at least for British boys, walking to school was correlated with higher levels of activity in other parts of the day.⁶⁷ Of course, this relationship may not be causal; it may simply reflect that boys who are naturally more active prefer to walk to school or that walking to school indicates that *other* opportunities for physical activity are also close by.

Changes in School and Child Care

Not only have children's methods of getting to school changed, but the environment once

they get there has evolved as well. In particular, the types of foods and beverages available at school have changed, as have physical education requirements. As noted, soft drink consumption has risen markedly over the past several decades, with some of the increase due to increased availability at school. Between 1977–78 and 1994–98, the share of overall soft drink consumption that took place in school cafeterias increased 3 percent.⁶⁸

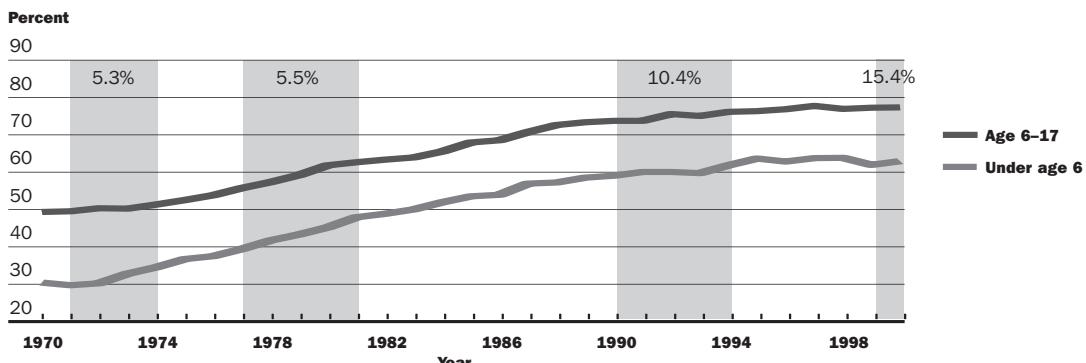
Much of the food available at schools is sold not in the cafeteria, however, but in vending machines. Over that same period, the share of soft drink consumption from vending machines increased 48 percent. And between 1994 and 2000, student access to vending machines increased from 61 to 67 percent in middle schools and from 88 to 96 percent in high schools.⁶⁹ Schools have found it quite lucrative to enter into exclusive “pouring rights” contracts with soft drink companies. In 2000, 73 percent of high schools had such a contract, as did 58 percent of middle schools, and even 42 percent of elementary schools.⁷⁰ Many schools also allow these companies to advertise on school grounds—46 percent of high schools, 29 percent of middle schools, and 13 percent of elementary schools.

School vending machines dispense not only soft drinks, but also snacks, while school stores and snack bars also sell soft drinks and snacks. In fact, among elementary schools with such student access, more than 50 percent sell cookies, crackers, cakes, pastries, and salty snacks. The share grows to more than 60 percent for middle schools and more than 80 percent for high schools.⁷¹ School cafeterias also sell these products à la carte, in competition with the National School Lunch Program. Sales of such competing foods are often an important part of the school budget, as most school food service programs must be self-supporting. These

sales often do more than subsidize the food service program, however. Increasingly, schools are using money raised through competitive food sales to supplement general budgets. One change in budgetary pressure on schools is the increased focus on academic accountability, which has also squeezed out other areas of study, such as nutrition and physical education, and even reduced the time available for lunch.⁷²

Some observers have speculated that these changes in the school environment may have contributed to the increase in childhood overweight and obesity, though relatively few serious studies have been undertaken.⁷³ In a recent working paper we found that school financial pressures are linked to the availability of junk food in middle and high schools. We estimated that a 10 percentage point increase in the availability of junk food increases average BMI by 1 percent. For adolescents with an overweight parent the effect is double.⁷⁴ Effects of this size can explain about a quarter of the increase in average BMI of adolescents over the 1990s. Diane Schanzenbach focuses not on the competing foods in schools but on the National School Lunch Program.⁷⁵ She finds that for children who enter kindergarten with similar obesity rates, those who eat the school lunch are about 2 percentage points more likely to be overweight at the end of first grade. Changes in the school lunch program, however, could not clearly explain the increase in obesity over time, although between 1991–92 and 1998–99 the number of calories in an elementary school lunch increased a little, from 715 to 738. For secondary school lunches, on the other hand, calories have declined over this same period, from 820 to 798.⁷⁶

As noted, it appears that physical activity has been squeezed out of schools to make room

Figure 6. Labor Force Participation Rate of Married Women with Children

Sources: NHANES data; LFP rates are from various years of the Census Bureau's *Statistical Abstract of the United States*.

Notes: Shaded areas represent years over which BMI measures are available. The percentage of children overweight in those NHANES data is shown.

for more academics. The National Association of Early Childhood Specialists in State Departments of Education recently stressed the importance of recess and free play, observing that 40 percent of elementary schools have reduced, deleted, or are considering deleting recess since 1989, when 90 percent of schools had some form of recess.⁷⁷ Trends in physical education (PE) in high school are a bit less clear, with enrollment moving up and down during the 1990s. The trend for daily PE attendance is downward, though, with about 42 percent of schools reporting it in 1991 and just 29 percent by 2003.⁷⁸ More generally, Karen MacPherson notes that since the late 1970s, children have seen a 25 percent drop in play and a 50 percent drop in unstructured outdoor activities.⁷⁹ One potential culprit is an increase in homework between 1981 and 1997, especially for the youngest students. Sandra Hofferth and John Sandberg report that while time spent studying was up 20 percent overall, for children aged six to eight it rose 146 percent.⁸⁰

Another source of a drop in unstructured play is the increase in the number of children in child care centers after school. Figure 6 il-

lustrates the basic trends in maternal employment for preschool-age and school-age children, again superimposing children's obesity rates over the four periods for which NHANES data are available. Note that the quality of child care used varies, so it is unclear whether being in child care per se affects children's obesity. Nonetheless, clearly the potential for less physical activity, more sedentary activities, more sweet drinks, and more energy-dense snacks exists when children move from parental care to a child care setting. It is worth noting, however, that the increase in labor force participation (LFP) appears fairly continuous from 1970 through about 1988 before flattening out in the 1990s, with no sudden increase between 1980 and 1988. Although the exact timing of the change is not entirely consistent with the timing of the increase in obesity, it remains worthwhile to investigate the changing role of parents more fully.

Changes in the Role of Parents

One major change over the past thirty years is the number of children with both parents (or their single parent) in the labor force. This change in the home environment may

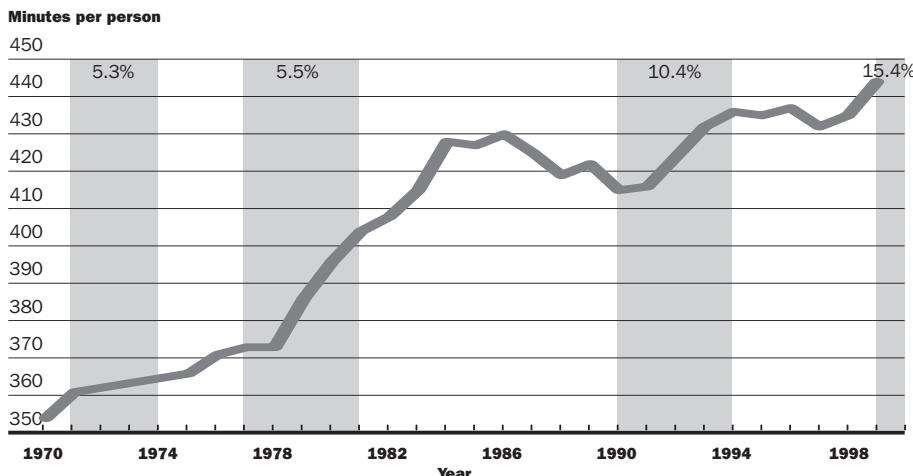
explain the increase in consumption both of food away from home and of pre-prepared foods, as families value convenience more highly. That is, the food market may have changed because of consumer demand stemming from the increase in households with no full-time homemaker. Note, though, that studies of the effect of maternal employment on the quality of children's diets tend to find no relationship.⁸¹ Nevertheless, a more recent study that directly examines how maternal employment affects childhood obesity concludes that a ten-hour increase in average hours worked each week over a child's lifetime increases the probability that the child is obese by about 1 percentage point.⁸² The study finds that it is not the work per se that affects children's overweight and obesity, but rather the intensity of the mothers' work. This difference may explain why previous studies found no real effect of work on children's diets and is in line with the idea that more time at work takes away from time spent preparing nutritious meals.

With less intensive work hours, mothers may also spend more time supervising active play. Similarly, having two parents working full time may also discourage walking or biking to school, as it may fit parents' schedules better to drop the children off at school on the way to work. To the extent that maternal employment affects children's physical activity, rather than nutrition, both sets of studies may be reconciled.

Increasing maternal employment may also affect the incidence or length of breastfeeding. The labor force participation rate of married women with children under age one, about 31 percent in 1975, increased to 54 and 55 percent by 1990 and 2003, respectively.⁸³ Nevertheless, the share of children ever breast-fed has been increasing, as has the

fraction breast-fed at older ages. Based on NHANES data, about 25 percent of children aged two to six in 1971–74 were ever breast-fed, compared to 26 percent in 1976–80. By 1988–94 almost 54 percent were ever breast-fed, increasing again by 1999–2002 to 62 percent. Over this same period the share breast-fed for at least three months rose from 55 percent to 74 percent, and the share breast-fed for at least one year rose from 7 percent to almost 25 percent. The National Survey of Family Growth does not show quite as consistent a pattern. It finds that the share of babies who were breast-fed rose from about 30 percent in 1972–74 to 58 percent in 1993–94. At the same time, the share breast-fed for three months or longer fell from 62 percent to 56 percent, after having risen to 68 percent in 1981–83.⁸⁴ Overall, though, these trends do not appear to make breast-feeding a good candidate for explaining the increase in childhood overweight.

Another area where parental roles may be important in explaining childhood obesity is television. For example, school-age children of working parents may now increasingly spend their afternoon hours unsupervised, which may increase their screen time. More generally, parents make decisions about the number and placement of televisions in a home. In 1970, 35 percent of homes had more than one television, 6 percent had three or more, and just 6 percent of sixth graders had one in their bedroom. By 1999 fully 88 percent of homes had more than one, 60 percent had three or more, and a whopping 77 percent of sixth graders had a television in their bedroom.⁸⁵ Nonetheless, the Hofferth and Sandberg study finds that for children aged three to twelve, weekly television viewing dropped four hours between 1981 and 1997.⁸⁶ Reliable and representative data on people's television viewing are relatively diffi-

Figure 7. Average Daily Minutes of TV Watching, All Viewers

Sources: NHANES data; daily television minutes are from various years of Nielsen Media's 2000 Report on Television.

Notes: Shaded areas represent years over which BMI measures are available. The percentage of children overweight in those data is shown.

cult to come by because of the need for detailed diary keeping. But Nielsen Media Research is well known for its measurements of television audiences, which are used to set advertising rates.

Based on Nielsen data, overall daily minutes of television watching have climbed in recent decades.⁸⁷ Figure 7 shows the average daily minutes per person from 1970 to 1999, again superimposing children's obesity rates over the four periods for which NHANES data are available. The overall daily increase of almost an hour and a half is relatively concentrated in the early 1980s (perhaps because of increasing cable penetration), the same time when the increase in obesity began in earnest. And viewing appears to be continuing to increase, as is obesity. These data, however, are for all television viewers, not children specifically. In its annual reports, Nielsen presents weekly viewing for separate age groups. Although these subgroup numbers are fairly noisy and not consistently defined across all years, children's viewing appears to be between 70 and 90 percent of

overall viewing, but it also seems to have declined over time. For example, in 1982 overall weekly viewing was 28.4 hours, while for children aged six to eleven it was 24 hours. For teens it was about 21 hours for females and 24 hours for males. In 1999 overall weekly viewing was still just over 28 hours, but viewing time of both younger children and teens had fallen to 19.7 hours.⁸⁸

Children may be substituting other forms of media, including videos, video games, and the Internet, for television watching. According to a 1999 study, children spent 19.3 hours a week watching television, another 2.3 hours playing video games, and 2.5 hours in front of the computer, implying just over one day (24.1 hours) of "screen time" a week.⁸⁹ Note that the television hours in this report are similar to the Nielsen numbers for that year. It may be reasonable to consider the overall Nielsen trend to be an approximation of children's screen time, with the decrease in children's television viewing relative to adults' resulting from the fact that children sometimes choose video games or play on the computer

instead of watching television. Although precise evidence on children's total screen time is not easily obtainable, the available data generally support the possibility that changes in screen time may be an important contributor to the increase in childhood obesity.

Perhaps one of the biggest influences of parents on children's overweight and obesity is genetic. As noted, genetics alone cannot explain the increases in obesity in recent decades. But parents may pass along to their children a susceptibility to overweight in the presence of energy imbalance. Changes in the environment that affect energy intake or expenditure could then trigger weight gain in this susceptible population. Differentiating clearly between the extent to which nature or nurture is responsible for the strong correlation between parent and child BMI can be difficult, though. It is known, for example, that parents influence children's food selection.⁹⁰ Genetics and behavior can thus interact as both parents and children gain weight in households where more energy-dense foods are available. Similarly, children's physical activity can be affected by how active their parents are. Again, genes and behavior will interact as households engage in more sedentary behaviors, with both parents and children gaining weight.

Conclusion

The increase in childhood obesity seems to have begun between 1980 and 1988 and then continued during the 1990s. This period also saw children's environments change in multiple ways that research suggests might be contributing to the obesity epidemic.

Over the critical time period, calorie-dense convenience foods and soft drinks were both increasingly available to children at school and increasingly advertised to children. Children consumed more soda pop. They also consumed more pre-prepared food and consumed more food away from home, as increases in dual-career or single-parent working families may have driven up demand for convenience. A host of environmental changes also contributed to reducing children's activity levels over the period in question. In particular, children traveled more in cars and were less likely to walk to school than they were in the early 1970s. Changes in the built environment and in their parents' work lives also made it more difficult for children to engage in safe, unsupervised (or lightly supervised) physical activity. Finally, children spent more time in such sedentary activities as watching television, playing video games, and using computers.

Taken together, research on obesity singles out no one critical cause of the increase in children's obesity. Rather, many complementary developments seem to have upset the crucial energy balance by simultaneously increasing children's energy intake and decreasing their energy expenditure. The challenge in formulating policies to address children's obesity is not necessarily to determine what changed to create the current epidemic, but rather, what is the most effective way to change children's environment and restore their energy balance going forward.

Notes

1. In imperial measurements, BMI is calculated as (weight in pounds/[height in inches]²) x 703.
2. National Institutes of Health, *Clinical Guidelines on the Identification, Evaluation, and Treatment of Overweight and Obesity in Adults: The Evidence Report*, NIH publication 98-4083 (September 1998).
3. William H. Dietz and Mary C. Bellizzi, "Introduction: The Use of Body Mass Index to Assess Obesity in Children," *American Journal of Clinical Nutrition* 70 (1999): 123S-125S.
4. In the medical literature the nomenclature used to describe children's and adults' weight is somewhat different. Adults with BMI above the cutoffs described above are either "overweight" or "obese." Children with BMIs above the 85th percentile are termed "at-risk-of-overweight," and those with BMIs above the 95th percentile are termed "overweight." To avoid confusion in comparisons between adults and children, we will term the former group of children "overweight" and the latter group "obese."
5. These percentile cutoffs are available at www.cdc.gov/nchs/about/major/nhanes/growthcharts/clinical_charts.htm#Clin%201 (September 26, 2005).
6. For more information on the National Health and Nutrition Examination Surveys, see the Centers for Disease Control website at www.cdc.gov/nchs/nhanes.htm (September 26, 2005).
7. These authors' calculations are based on the National Health and Nutrition Examination Surveys. The data include children aged two to nineteen and adults aged twenty to seventy. We exclude individuals with a BMI above 50, which drops a small number (fewer than 100) of individuals in each year. The data are weighted using the examination weight since we use the height and weight that are collected in the medical examination module to define BMI.
8. Obesity rates based on BMI cutoffs may underestimate obesity among adult women. The cutoff to define obese for both adult women and adult men is 30, but men likely have more lean muscle mass for a given BMI.
9. Robert C. Whitaker and others, "Predicting Obesity in Young Adulthood from Childhood and Parental Obesity," *New England Journal of Medicine* 337 (1997): 869-73.
10. Obesity rates are also higher among Hispanic children than among white non-Hispanic children. However, it is impossible to consistently define Hispanic across the different NHANES surveys. "Low income" roughly corresponds to children in families in the lowest quartile of family income. However, each NHANES survey reports family income in categories, and the categories do not always correspond to the level of family income that defines the lowest quartile. The income cutoffs used for each year and the mapping between NHANES income categories and income quartiles are available from the authors on request.
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